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(54) **SYSTEM AND METHOD FOR GENERATION OF CONCEPT STRUCTURES BASED ON SUB-CONCEPTS**

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CPC combination set(s) only.
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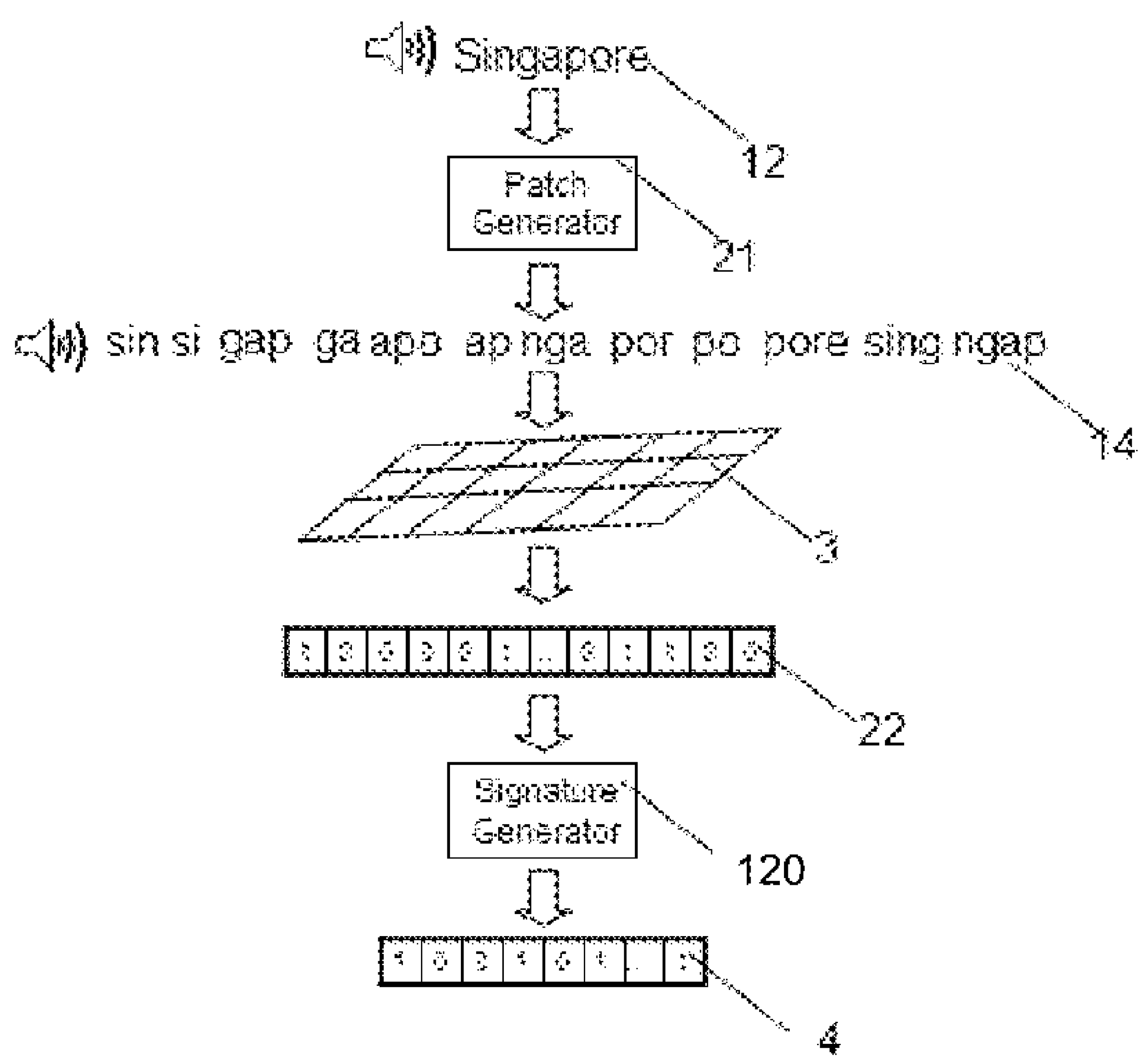
(57) **ABSTRACT**

A method and system for method for generating concept structures are disclosed. The method comprises receiving a request to create a new concept structure, wherein the request includes at least a multimedia data element (MMDE) related to the new concept structure; querying a deep-content-classification (DCC) system using the MMDE to find at least one sub-concept, wherein a sub-concept is a concept structure that partially matches the received MMDE; checking if the at least one sub-concept satisfies at least one predefined logic rule; generating one or more sub-concepts from the at least MMDE; and generating the new concept structure using one or more sub-concepts out of the at least one sub-concepts that satisfies the predefined logic rule.

17 Claims, 8 Drawing Sheets



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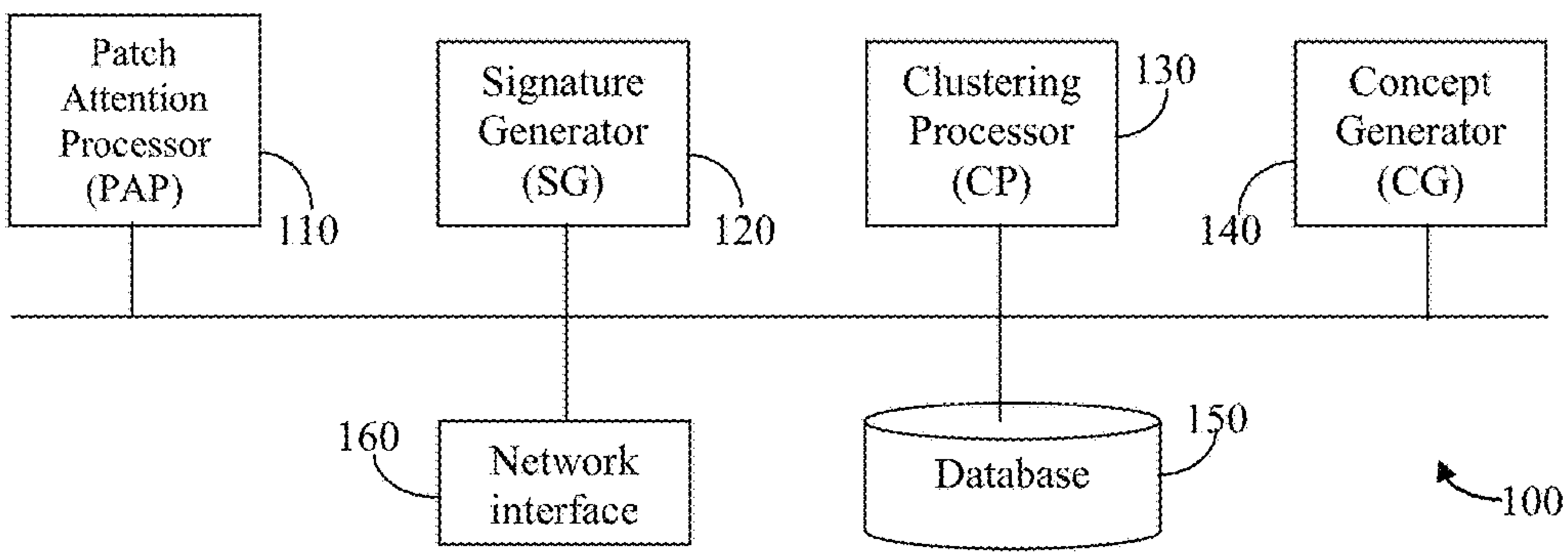
Patch
Attention
Processor
(PAP)
110
Signature
Generator
(SG)
120
Clustering
Processor
(CP)
130
Concept
Generator
(CG)
140
160
Network
interface
Database
150
100

FIG. 1

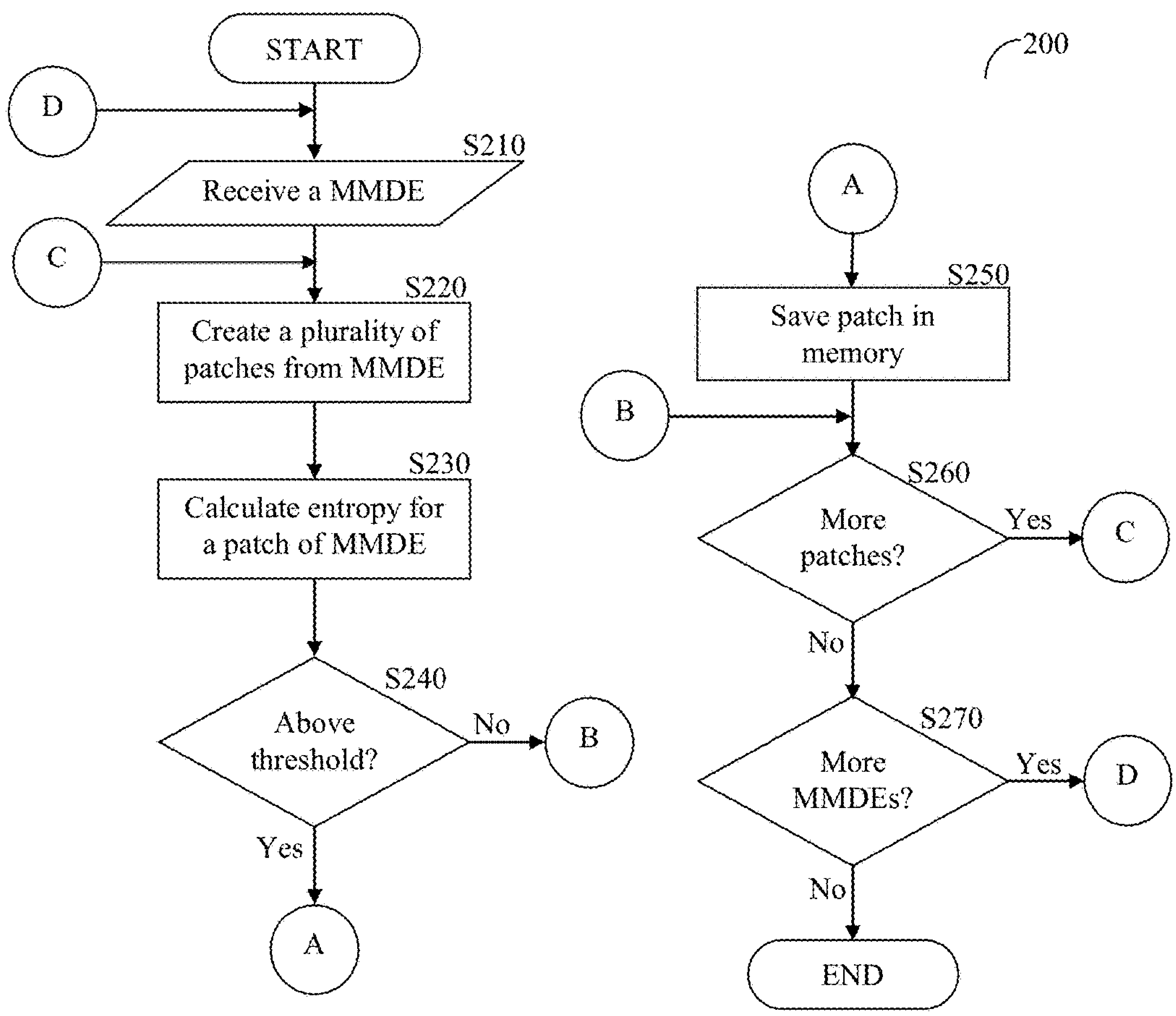
200
START
D
S210
Receive a MMDE
C
S220
Create a plurality of patches from MMDE
S230
Calculate entropy for a patch of MMDE
S240
Above threshold?
No
B
Yes
A
A
S250
Save patch in memory
B
S260
More patches?
Yes
C
No
S270
More MMDEs?
Yes
D
No
END

FIG. 2

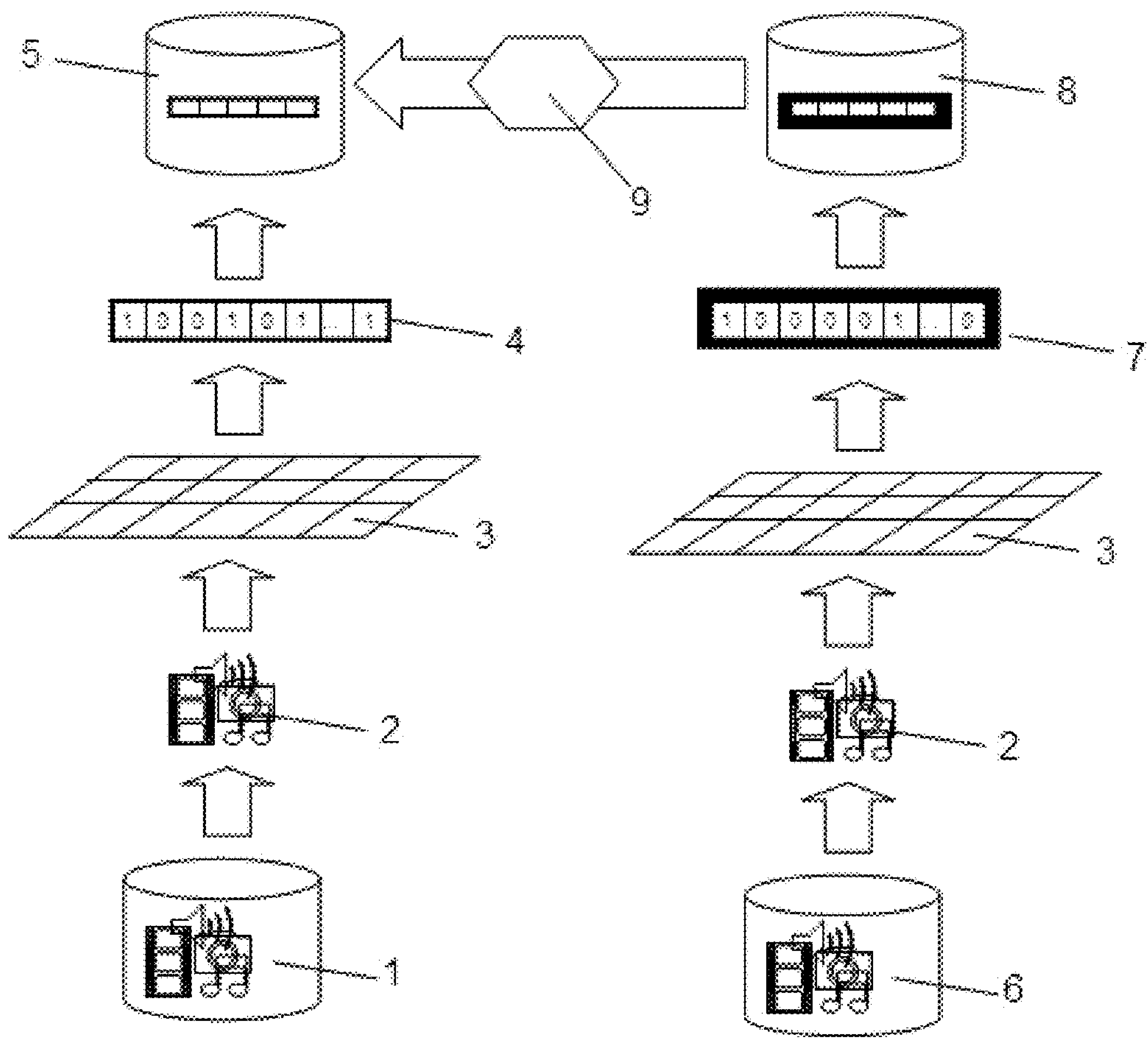

FIG. 3

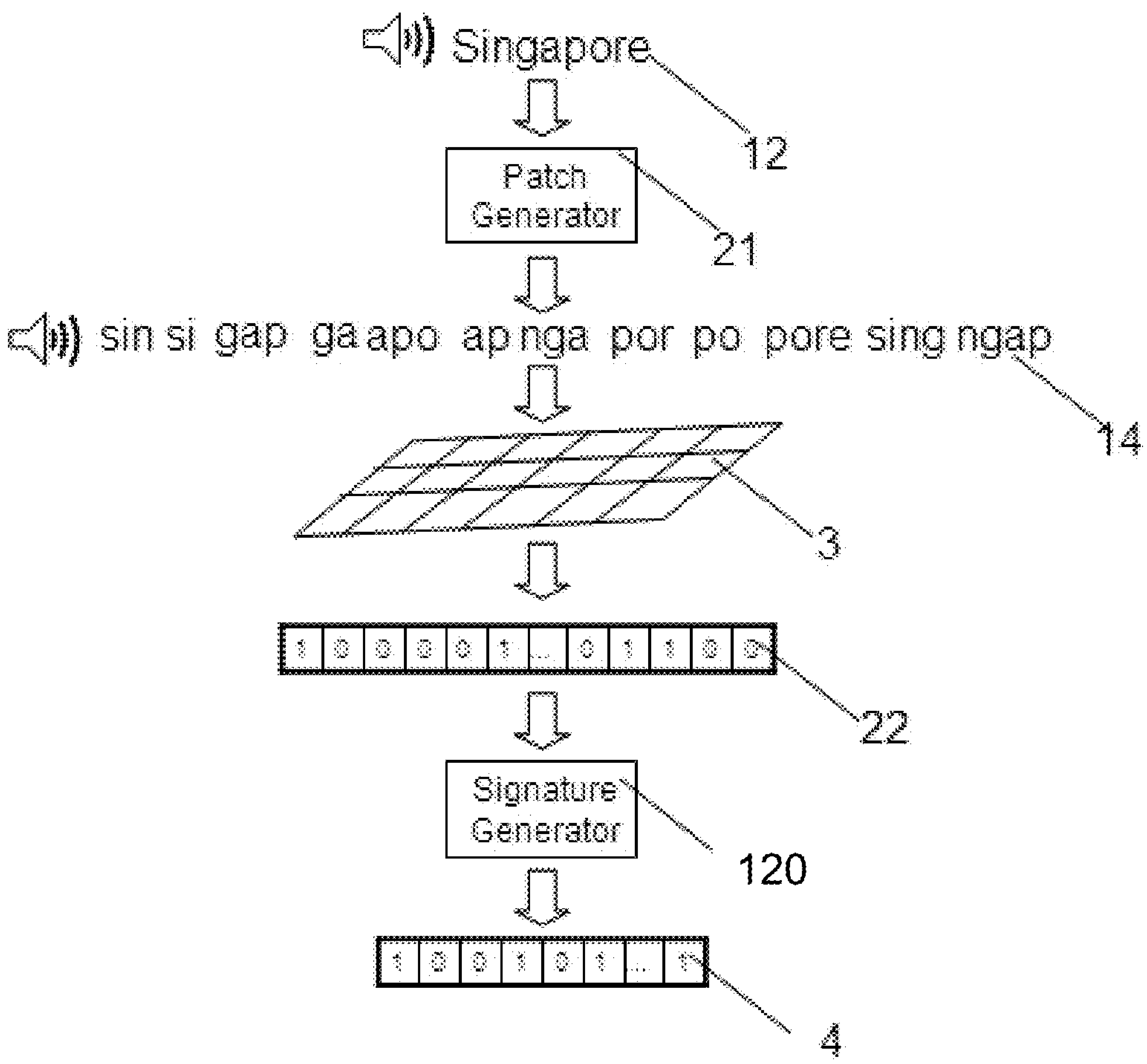
Singapore
12
Patch Generator
21
sin si gap ga apo ap nga por po pore sing ngap
14
3
22
Signature Generator
120
4

FIG. 4

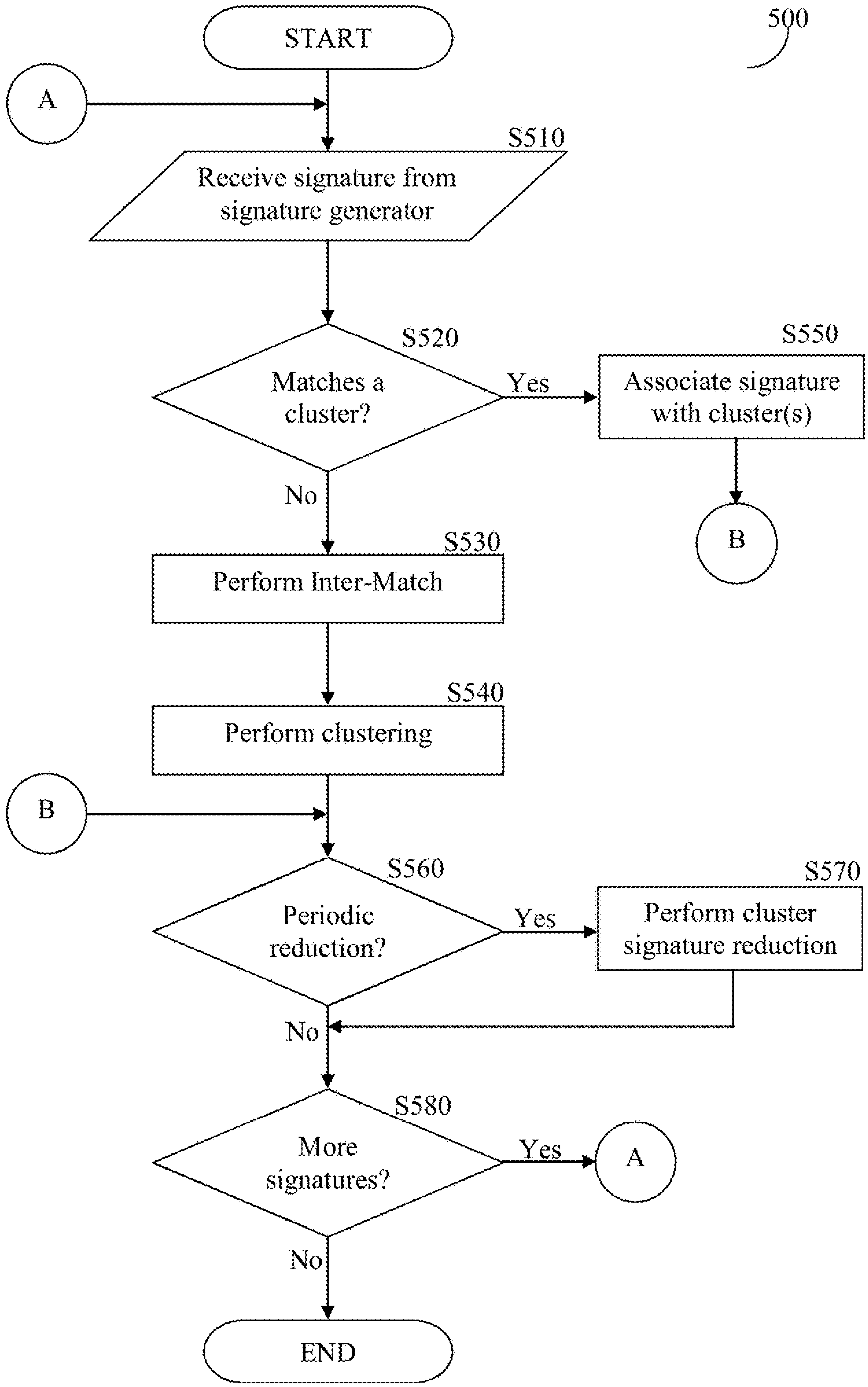
500
START
A
S510
Receive signature from signature generator
S520
Matches a cluster?
Yes
S550
Associate signature with cluster(s)
No
B
S530
Perform Inter-Match
S540
Perform clustering
B
S560
Periodic reduction?
Yes
S570
Perform cluster signature reduction
No
S580
More signatures?
Yes
A
No
END

FIG. 5

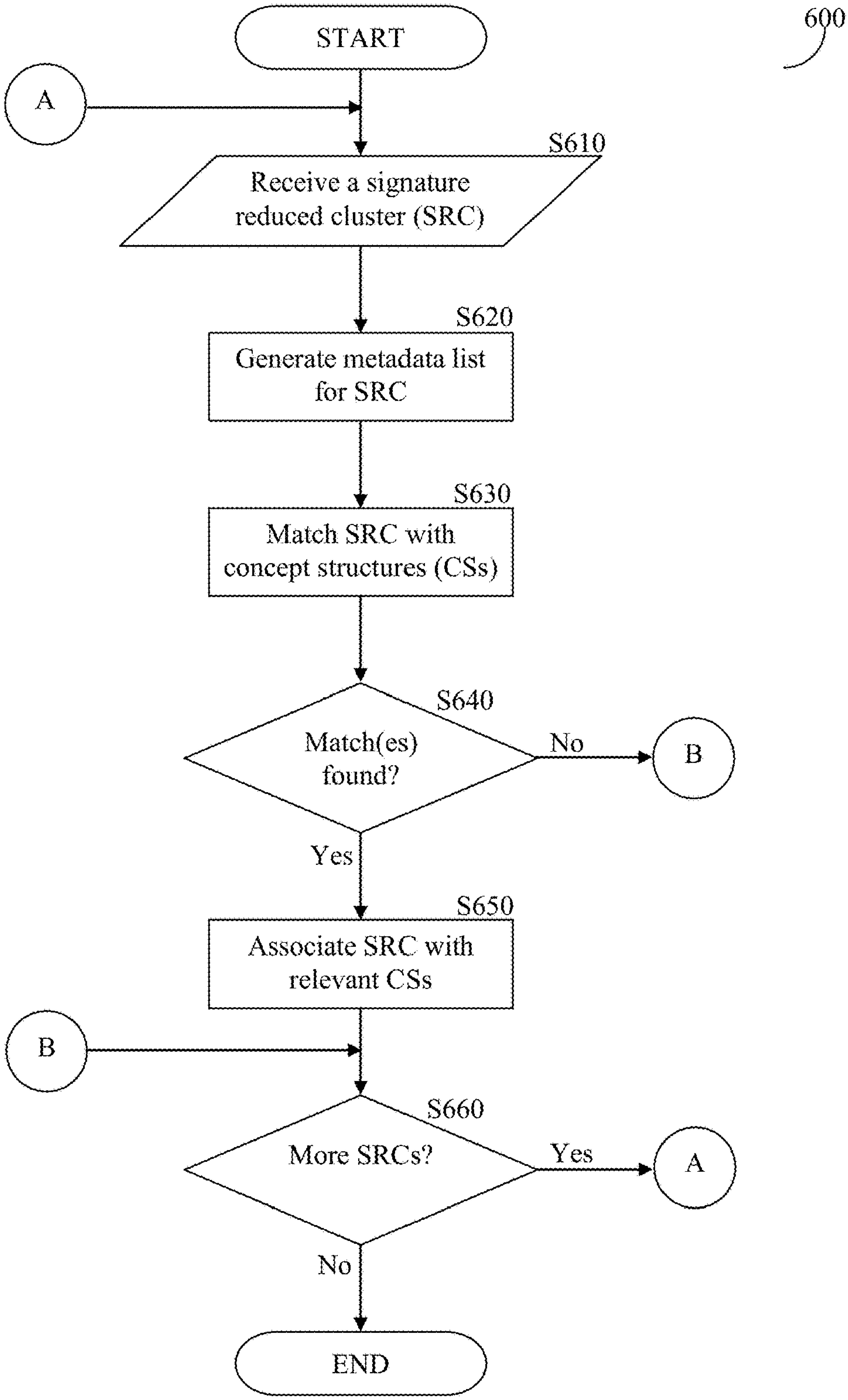
600
START
A
S610
Receive a signature reduced cluster (SRC)
S620
Generate metadata list for SRC
S630
Match SRC with concept structures (CSs)
S640
Match(es) found?
No
B
Yes
S650
Associate SRC with relevant CSs
B
S660
More SRCs?
Yes
A
No
END

FIG. 6

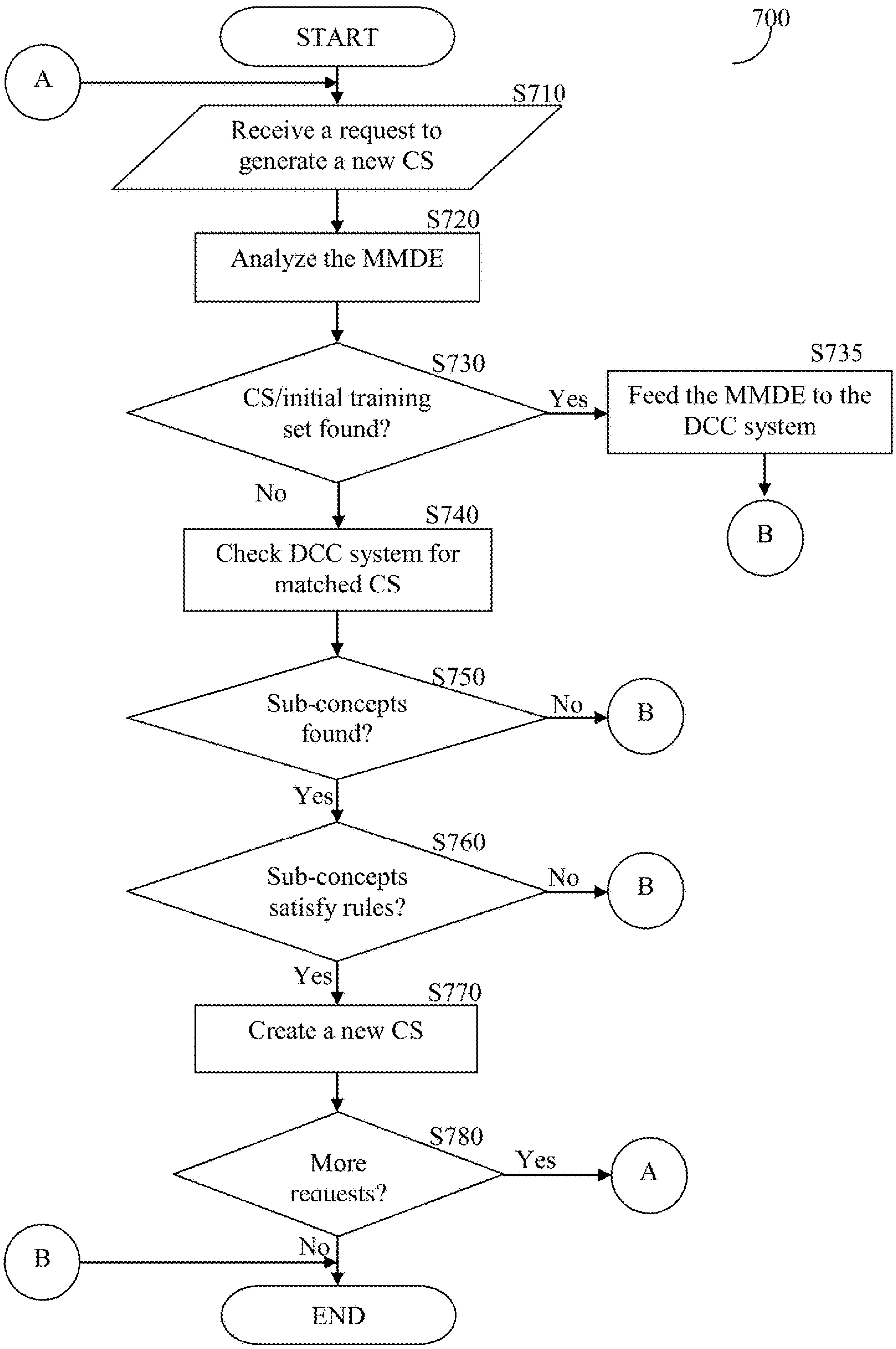
700
START
A
S710
Receive a request to generate a new CS
S720
Analyze the MMDE
S730
CS/initial training set found?
Yes
S735
Feed the MMDE to the DCC system
B
No
S740
Check DCC system for matched CS
S750
Sub-concepts found?
No
B
Yes
S760
Sub-concepts satisfy rules?
No
B
Yes
S770
Create a new CS
S780
More requests?
Yes
A
B
No
END

FIG. 7

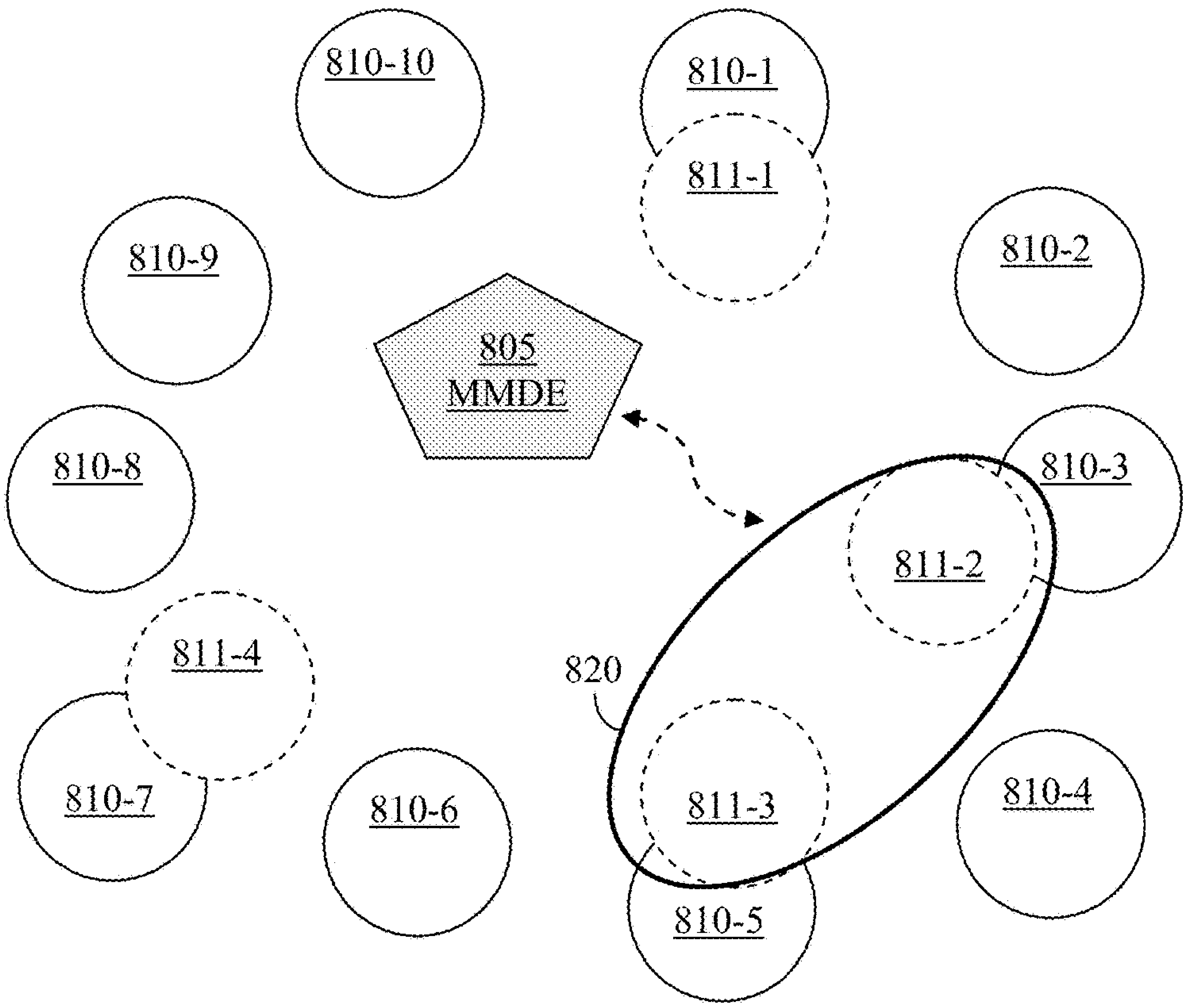
810-10
810-1
811-1
810-2
810-9
805
MMDE
810-8
810-3
811-2
811-4
820
810-7
810-6
811-3
810-4
810-5

FIG. 8

SYSTEM AND METHOD FOR GENERATION OF CONCEPT STRUCTURES BASED ON SUB-CONCEPTS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part (CIP) application of U.S. patent application Ser. No. 13/602,858 filed Sep. 4, 2012, which is a continuation of U.S. patent application Ser. No. 12/603,123, filed on Oct. 21, 2009, now issued as U.S. Pat. No. 8,266,185, which is a continuation-in-part of:

(1) U.S. patent application Ser. No. 12/084,150 having a filing date of Apr. 7, 2009, now allowed, which is the National Stage of International Application No. PCT/IL2006/001235, filed on Oct. 26, 2006, which claims foreign priority from Israeli Application No. 171577 filed on Oct. 26, 2005 and Israeli Application No. 173409 filed on 29 Jan. 2006;

(2) U.S. patent application Ser. No. 12/195,863, filed Aug. 21, 2008, now issued as U.S. Pat. No. 8,326,775, which claims priority under 35 USC 119 from Israeli Application No. 185414, filed on Aug. 21, 2007, and which is also a continuation-in-part of the above-referenced U.S. patent application Ser. No. 12/084,150;

(3) U.S. patent application Ser. No. 12/348,888, filed Jan. 5, 2009, now pending, which is a CIP of the above-referenced U.S. patent application Ser. No. 12/195,863, and the above-referenced U.S. patent application Ser. No. 12/084,150;

(4) U.S. patent application Ser. No. 12/538,495, filed Aug. 10, 2009, now issued as U.S. Pat. No. 8,312,031, which is a CIP of the above-referenced U.S. patent application Ser. No. 12/084,150, the above-referenced U.S. patent application Ser. No. 12/195,863, and the above-referenced U.S. patent application Ser. No. 12/348,888.

All of the applications referenced above are herein incorporated by reference.

TECHNICAL FIELD

The invention generally relates to content-management and search engines and more particularly relates to the collection, clustering and creation of concept structures of multimedia data elements for the purpose of effective storage, management, knowledge database generation and search.

BACKGROUND

With the abundance of multimedia data made available through various means in general and the Internet and world-wide web (WWW) in particular, there is a need for effective ways of searching for multimedia data, and management of such multimedia data. Searching, organizing and management of multimedia data in general and video data in particular may be challenging at best due to the difficulty of representing and comparing the information embedded in the video content, and due to the scale of information that needs to be checked. Moreover, when it is necessary to find a content of a video by means of textual query, prior art cases revert to various metadata that textually describe the content of the multimedia data. However, such content may be abstract and complex by nature and not necessarily adequately defined by the existing and/or attached metadata.

The rapid increase in multimedia databases, accessible for example through the Internet, calls for the application of

new methods of representation of information embedded in video content. Searching for multimedia in general and for video data in particular is challenging due to the huge amount of information that has to first be indexed, classified and clustered. Moreover, prior art techniques revert to model-based methods to define and/or describe multimedia data. However, by its very nature, the structure of such multimedia data may be too abstract and/or complex to be adequately represented by means of metadata. The difficulty arises in cases where the target sought for multimedia data is not adequately defined in words, or by respective metadata of the multimedia data. For example, it may be desirable to locate a car of a particular model in a large database of video clips or segments. In some cases the model of the car would be part of the metadata but in many cases it would not. Moreover, the car may be oriented at angles different from the angles of a specific photograph of the car that is available as a search item. Similarly, if a piece of music, as in a sequence of notes, is to be found, it is not necessarily the case that the notes are known in their metadata form within the available content, or for that matter, the search pattern may just be a brief audio clip.

A system implementing a computational architecture (hereinafter "the Architecture") that is based on a PCT patent application publication number WO2007/049282 and published on May 3, 2007, entitled "A Computing Device, a System and a Method for Parallel Processing of Data Streams", assigned to common assignee, is hereby incorporated by reference for all the useful information it contains. Generally, the Architecture consists of a large ensemble of randomly, independently generated, heterogeneous processing cores, mapping in parallel data-segments onto a high-dimensional space and generating compact signatures for classes of interest.

Searching multimedia data has been a challenge of past years and has therefore received considerable attention. Early systems would take a multimedia data element in the form of, for example an image, compute various visual features from it and then search one or more indexes to return images with similar features. In addition values for these features and appropriate weights reflecting their relative importance could be also used. Searching and indexing techniques have improved over time to handle various types of multimedia inputs with an ever increasing effectiveness. However, since the exponential growth of the use of the Internet and the multimedia data available there, these prior art systems have become less effective in handling the multimedia data, due to the vast amounts of data already existing, as well as the speed at which new ones are added.

Searching has therefore become a significant challenge and even the addition of metadata to assist in the search has limited functionality. First, metadata may be inaccurate or not fully descriptive of the multimedia data, and second, not every piece of multimedia data can be accurately enough described by a sequence of textual metadata. A query model for a search engine has some advantages, such as comparison and ranking of images based on objective visual features, rather than on subjective image annotations. However, the query model has its drawbacks as well. Certainly when no metadata is available and only the multimedia data needs to be used, the process requires significant effort. Those skilled in the art will appreciate that there is no known intuitive way of describing multimedia data. Therefore, a large gap may be found between a user's perception or conceptual understanding of the multimedia data and the way it is actually stored and manipulated by a search engine.

The current generation of web applications has become more and more effective at aggregating massive amounts of data of various multimedia content, such as pictures, videos, clips, paintings and mash-ups, and is capable of slicing and dicing it in different ways, as well as searching it and displaying it in an organized fashion, by using, for example, concept networks. A concept may enable understanding of multimedia data from its related concept. However, current art is unable to add any real "intelligence" to the mix, i.e., no new knowledge is extracted from the multimedia data that are aggregated by existing systems. Moreover, the existing systems tend to be non-scalable due to the vast amounts of data they have to handle. This, by definition, hinders the ability to provide high quality searching for multimedia content.

There is therefore a need in the art to overcome the deficiencies of the prior art solutions and provide a solution for generating concepts when no prior knowledge for creating such concepts is available.

SUMMARY

Certain embodiments disclosed herein include a method and system for method for generating concept structures. The method comprises receiving a request to create a new concept structure, wherein the request includes at least a multimedia data element (MMDE) related to the new concept structure; querying a deep-content-classification (DCC) system using the MMDE to find at least one sub-concept, wherein a sub-concept is a concept structure that partially matches the received MMDE; checking if the at least one sub-concept satisfies at least one predefined logic rule; generating one or more sub-concepts from the at least MMDE; and generating the new concept structure using one or more sub-concepts out of the at least one sub-concepts that satisfies the predefined logic rule.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter that is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other objects, features and advantages of the invention will be apparent from the following detailed description taken in conjunction with the accompanying drawings.

FIG. **1** is a diagram of a DCC system for creating concept structures.

FIG. **2** is a flowchart illustrating the operation of the patch attention processor of the DCC system.

FIG. **3** is a block diagram depicting the basic flow of information in a large-scale video matching system.

FIG. **4** is a diagram showing the flow of patches generation, response vector generation, and signature generation in a large-scale speech-to-text system.

FIG. **5** is a flowchart illustrating the operation of the clustering processor of the DCC system.

FIG. **6** is a flowchart illustrating the operation of the concept generator of the DCC system.

FIG. **7** is a flowchart illustrating the operation of generating concepts based on identification of sub-concepts according to one embodiment.

FIG. **8** is an example for the method for generating concepts based on identification of sub-concepts.

DETAILED DESCRIPTION

The embodiments disclosed herein are only examples of the many possible advantageous uses and implementations of the innovative teachings presented herein. In general, statements made in the specification of the present application do not necessarily limit any of the various claimed embodiments. Moreover, some statements may apply to some inventive features but not to others. In general, unless otherwise indicated, singular elements may be in plural and vice versa with no loss of generality. In the drawings, like numerals refer to like parts through several views.

A large-scale web-platform for a multimedia deep-content-classification (DCC) system configured to continuously create a knowledge database for multimedia data can be utilized to achieve the embodiments disclosed herein. The DCC system initially receives a large number of multimedia data elements (MMDEs) to create a knowledge base that is condensed into concept structures that are efficient to store, retrieve and check for matches. As new MMDEs are collected they are efficiently added to the knowledge base and concept structures, such that the computing resources requirement for achieving this operation is generally sub-linear rather than linear or exponential. The DCC system extracts patterns from each MMDE and selects the important/salient patterns for the creation of signatures thereof. A process of inter-matching between the patterns found by clustering is followed by reduction in the number of signatures in a cluster to a minimum that maintains matching and enables generalization to new MMDEs. Metadata respective of the MMDEs is thereby produced, forming together with the reduced clusters into a concept structure.

FIG. **1** shows an exemplary and non-limiting diagram of a DCC system **100** for creating concept structures. The DCC system **100** is configured to receive multimedia data elements (MMDEs), for example from the Internet via the network interface **160**. The MMDEs include, but are not limited to, images, graphics, video streams, video clips, audio streams, audio clips, video frames, photographs, images of signals, combinations thereof, and portions thereof. The images of signals are images such as, but not limited to, medical signals, geophysical signals, subsonic signals, supersonic signals, electromagnetic signals, and infrared signals.

The MMDEs may be stored in a database (DB) **150** or kept in the DB **150** for future retrieval of the respective multimedia data element. Such a reference may be, but is not limited to, a universal resource locator (URL). Every MMDE in the DB **150**, or referenced therefrom, is then processed by a patch attention processor (PAP) **110** resulting in a plurality of patches that are of specific interest, or otherwise of higher interest than other patches. A more general pattern extraction, such as an attention processor (AP) may also be used in lieu of patches. The AP receives the MMDE that is partitioned into items; an item may be an extracted pattern or a patch, or any other applicable partition depending on the type of the MMDE. The functions of the PAP **110** are described herein below in more detail.

Those patches that are of higher interest are then used by a signature generator (SG) **120** to generate signatures respective of the patch. The operation of the signature generator (SG) **120** is described in more detail herein below. A clustering process (CP) **130** initiates a process of inter-matching of the signatures once it determines that there are a number of patches that are above a predefined threshold. The threshold may be defined to be large enough to enable proper and meaningful clustering. With a plurality of clusters a process of clustering reduction takes place so as to extract the most useful data about the cluster and keep it at an optimal size to produce meaningful results. The process of cluster reduction is continuous. When new signatures are provided after the initial phase of the operation of the CP **130**, the new signatures may be immediately checked against the reduced clusters to save on the operation of the CP **130**. A more detailed description of the operation of the CP **130** is provided herein below.

A concept generator (CG) **140** operates to create concept structures from the reduced clusters provided by the CP **130**. Each concept structure comprises a plurality of metadata associated with the reduced clusters. The result is a compact representation of a concept that can now be easily compared against a MMDE to determine if the received MMDE matches a concept structure stored, for example in the DB **150**, by the CG **140**. This can be done, for example and without limitation, by providing a query to the DCC system **100** for finding a match between a concept structure and a MMDE. A more detailed description of the operation of the CG **140** is provided herein below.

It should be appreciated that the DCC system **100** can generate a number of concept structures significantly smaller than the number of MMDEs. For example, if one billion (10^9) MMDEs need to be checked for a match against another one billon MMDEs, typically the result is that no less than $10^9 \times 10^9 = 10^{18}$ matches have to take place, a daunting undertaking. The DCC system **100** would typically have around 10 million concept structures or less, and therefore at most only $2 \times 10^6 \times 10^9 = 2 \times 10^{15}$ comparisons need to take place, a mere 0.2% of the number of matches that have had to be made by other solutions. As the number of concept structures grows significantly slower than the number of MMDEs, the advantages of the DCC system **100** would be apparent to one with ordinary skill in the art.

The operation of the PAP **110** will now be provided in greater detail with respect to an image as the MMDE. However, this should not be understood as to limit the scope of the invention; other types of MMDEs are specifically included herein and may be handled by the PAP **110**.

FIG. **2** depicts an exemplary and non-limiting flowchart **200** of the operation of the PAP **110**. In S**210** the PAP **110** receives a MMDE from a source for such MMDEs. Such a source may be a system that feeds the DCC system **100** with MMDEs or other sources for MMDEs, for example the world-wide-web (WWW). In S**220** the PAP **110** creates a plurality of patches from the MMDE. A patch of an image is defined by, for example, its size, scale, location and orientation. A patch may be, for example and without limitation, a portion of an image of a size 20 pixels by 20 pixels of an image that is 1,000 pixels by 500 pixels. In the case of audio, a patch may be a segment of audio 0.5 seconds in length from a 5 minute audio clip. In S**230** a patch not previously checked is processed to determine its entropy. The entropy is a measure of the amount of interesting information that may be present in the patch. For example, a continuous color of the patch has little interest whereas sharp edges, corners or borders, will result in higher entropy representing a lot of interesting information. The plurality of statistically independent cores, the operation of which is discussed in more detail herein below, is used to determine the level-of-interest of the image; a process of voting takes place to determine whether the patch is of interest or not.

In S**240**, it is checked whether the entropy was determined to be above a predefined threshold, and if so execution continues with S**250**; otherwise, execution continues with S**260**. In S**250** the patch having entropy above the threshold is stored for future use by the SG **120** in, for example, DB **150**. In S**260** it is checked whether there are more patches of the MMDE to be checked, and if so execution continues with S**220**; otherwise execution continues with S**270**. In S**270** it is checked whether there are additional MMDEs, and if so execution continues with S**210**; otherwise, execution terminates. It would be appreciated by those of skill in the art that this process reduces the information that must be handled by the DCC system **100** by focusing on areas of interest in the MMDEs rather than areas that are less meaningful for the formation of a concept structure.

A high-level description of the process for large scale video matching performed by the Matching System is depicted in FIG. **3**. Video content segments **2** from a Master DB **6** and a Target DB **1** are processed in parallel by a large number of independent computational Cores **3** that constitute the Architecture. Further details on the computational Cores generation are provided below. The independent Cores **3** generate a database of Robust Signatures and Signatures **4** for Target content-segments **5** and a database of Robust Signatures and Signatures **7** for Master content-segments **8**. An exemplary and non-limiting process of signature generation for an audio component is shown in detail in FIG. **4**. Referring back to FIG. **3**, at the final step, Target Robust Signatures and/or Signatures are effectively matched, by a matching algorithm **9**, to Master Robust Signatures and/or Signatures database to find all matches between the two databases.

A brief description of the operation of the SG **120** is therefore provided, this time with respect to a MMDE which is a sound clip. However, this should not be understood as to limit the scope of the invention and other types of MMDEs are specifically included herein and may be handled by SG **120**. To demonstrate an example of signature generation process, it is assumed, merely for the sake of simplicity and without limitation on the generality of the disclosed embodiments, that the signatures are based on a single frame, leading to certain simplification of the computational core's generation. The Matching System shown in FIG. **3** is extensible for signatures generation capturing the dynamics in-between the frames and the information of the frame's patches.

The signatures generation process will be described with reference to FIG. **4**. The first step in the process of signatures generation from a given speech-segment is to break-down the speech-segment to K patches **14** of random length P and random position within the speech segment **12**. The breakdown is performed by the patch generator component **21**. The value of K is determined based on optimization, considering the tradeoff between accuracy rate and the number of fast matches required in the flow process of the Matching System. In the next step, all the K patches are injected in parallel to all L computational Cores **3** to generate K response vectors **22**. The vectors **22** are fed into the SG **120** to produce a Signatures and Robust Signatures **4**.

In order to generate Robust Signatures, i.e., Signatures that are robust to additive noise L (where L is an integer equal to or greater than 1) computational cores are utilized in the Matching System. A frame i is injected into all the Cores. The computational cores **3** generate two binary response vectors: $\vec{S}$ which is a Signature vector, and $\overrightarrow{RS}$ which is a Robust Signature vector.

For generation of signatures robust to additive noise, such as White-Gaussian-Noise, scratch, etc., but not robust to distortions, such as crop, shift and rotation, etc., a core $C_i=\{n_i\}$ $(1 \le i \le L)$ may consist of a single leaky integrate-to-threshold unit (LTU) node or more nodes. The node ni equations are:

$$V_i = \sum_j w_{ij} k_j$$

ni=□(Vi−Thx); □ is a Heaviside step function; w_{ij} is a coupling node unit (CNU) between node i and image component j (for example, grayscale value of a certain pixel j); k_j is an image component j (for example, grayscale value of a certain pixel j); Th_x is a constant Threshold value, where x is 'S' for Signature and 'RS' for Robust Signature; and V_i is a Coupling Node Value.

The Threshold values Th_x are set differently for Signature generation and for Robust Signature generation. For example, for a certain distribution of V_i values (for the set of nodes), the thresholds for Signature (ThS) and Robust Signature (ThRS) are set apart, after optimization, according to at least one or more of the following criteria:

For: $V_i > Th_{RS}$

$$1-p(V>Th_S)-1-(1-\varepsilon)^l \ll 1 \qquad \text{I}$$

i.e., given that l nodes (cores) constitute a Robust Signature of a certain image l, the probability that not all of these l nodes will belong to the Signature of same, but noisy image, ⁐ is sufficiently low (according to a system's specified accuracy).

$$p(V_i>Th_{RS}) \approx l/L \qquad \text{II}$$

i.e., approximately 1 out of the total L nodes can be found to generate Robust Signature according to the above definition.

Both Robust Signature and Signature are generated for certain frame *i*. III

It should be understood that the creation of a signature is a unidirectional compression where the characteristics of the compressed data are maintained but the compressed data cannot be reconstructed. Therefore, a signature can be used for the purpose of comparison to another signature without the need of comparison of the original data. The detailed description of the Signature generation can be found U.S. Pat. Nos. 8,326,775 and 8,312,031, assigned to common assignee, which are hereby incorporated by reference for all the useful information they contain.

Computational Core generation is a process of definition, selection and tuning of the Architecture parameters for a certain realization in a specific system and application. The process is based on several design considerations, such as: (a) The Cores should be designed so as to obtain maximal independence, i.e. the projection from a signal space should generate a maximal pair-wise distance between any two Cores' projections into a high-dimensional space; (b) The Cores should be optimally designed for the type of signals, i.e. the Cores should be maximally sensitive to the spatio-temporal structure of the injected signal, for example, and in particular, sensitive to local correlations in time and space. Thus, in some cases a Core represents a dynamic system, such as in state space, phase space, edge of chaos, etc., which is uniquely used herein to exploit their maximal computational power, and, (c) The Cores should be optimally designed with regard to invariance to a set of signal distortions, of interest in relevant applications. Detailed description of the Computational Core generation, the computational architecture, and the process for configuring such cores is discussed in more detail in the co-pending U.S. patent application Ser. No. 12/084,150 referenced above.

Hence, signatures are generated by the SG **120** responsive of patches received either from the PAP **110**, or retrieved from the DB **150**, as discussed hereinabove. It should be noted that other ways for generating signatures may also be used for the purpose the DCC system **100**. Furthermore, as noted above, the array of computational cores may be used by the PAP **110** for the purpose of determining if a patch has an entropy level that is of interest for signature generation according to the principles of the invention. The generated signatures are stored, for example, in the DB **150**, with reference to the MMDE and the patch for which it was generated thereby enabling back annotation as may be necessary.

Portions of the CP **130** have been discussed in detail in the co-pending U.S. patent application Ser. No. 12/507,489, entitled "Unsupervised Clustering of Multimedia Data Using a Large-Scale Matching System", filed Jul. 22, 2009, assigned to common assignee (the "'489 Application"), and which is hereby incorporated for all that it contains. In accordance with an embodiment an inter-match process and clustering thereof is utilized. The process can be performed on signatures provided by the SG **120**. It should be noted though that this inter-matching and clustering process is merely an example for the operation of the CP **130** and other inter-matching and/or clustering processes may be used for the purpose of the invention.

Following is a brief description of the inter-match and clustering process. The unsupervised clustering process maps a certain content-universe onto a hierarchical structure of clusters. The content-elements of the content-universe are mapped to signatures, when applicable. The signatures of all the content-elements are matched to each other, and consequently generate the inter-match matrix. The described clustering process leads to a set of clusters. Each cluster is represented by a small/compressed number of signatures, for example signatures generated by SG **120** as further explained hereinabove, which can be increased by variants. This results in a highly compressed representation of the content-universe. A connection graph between the multimedia data elements of a cluster may be stored. The graph can then be used to assist a user searching for data to move along the graph in the search of a desired multimedia data element.

In another embodiment, upon determination of a cluster, a signature for the whole cluster may be generated based on the signatures of the multimedia data elements that belong to the cluster. It should be appreciated that using a Bloom filter may be used to reach such signatures. Furthermore, as the signatures are correlated to some extent, the hash functions of the Bloom filter may be replaced by simpler pattern detectors, with the Bloom filter being the upper limit.

While signatures are used here as the basic data elements, it should be realized that other data elements may be clustered using the techniques discussed above. For example, a system generating data items is used, where the data items generated may be clustered according to the disclosed principles. Such data items may be, without limitation, multimedia data elements. The clustering process may be performed by dedicated hardware or by using a computing device having storage to store the data items generated by the system and then performing the process described herein above. Then, the clusters can be stored in memory for use as may be deemed necessary.

The CP **130** further uses an engine designed to reduce the number of signatures used in a structure, in a sense, extracting only the most meaningful signatures that identify the cluster uniquely. This can be done by testing a removal of a signature from a cluster and checking if the MMDEs associated with the cluster are still capable of being recognized by the cluster through signature matching.

The process of signature extraction is on-going as the DCC system **100** operates. It should be noted that after initialization, upon signature generation by the SG **120** of a MMDE, its respective signature is first checked against the clusters to see if there is a match and if so it may not be necessary to add the signature to the cluster or clusters but rather simply by associating the MMDE with the identified cluster or clusters. However, in some cases where additional refinement of the concept structure is possible, the signature may be added, or at times even replace one or more of the existing signatures in the reduced cluster. If no match is found then the process of inter-matching and clustering may take place.

FIG. **5** depicts an exemplary and non-limiting flowchart **500** of the operation of the CP **130**. In S**510** a signature of a MMDE is received, for example from the SG **120**. In S**520** it is checked whether the signature matches one or more existing clusters and if so execution continues with S**550**; otherwise, execution continues with S**530**. In S**530** an inter-match between a plurality of signatures previously received by the DCC system **100** is performed, for example in accordance with the principles of the '489 Application. As may be necessary the DB **150** may be used to store results or intermediate results as the case may be, however, other memory elements may be used. In S**540** a clustering process takes place, for example in accordance with the principles of the '489 Application. As may be necessary the DB **150** may be used to store results or intermediate results as the case may be, however, other memory elements may be used.

In S**550**, the signature identified to match one or more clusters is associated with the existing cluster(s). In S**560** it is checked whether a periodic cluster reduction is to be performed, and if so execution continues with S**570**; otherwise, execution continues with S**580**. In S**570** the cluster reduction process is performed. Specifically, the purpose of the operation is to ensure that in the cluster there remains the minimal number of signatures that still identify all of the MMDEs that are associated with the signature reduced cluster (SRC). This can be performed, for example, by attempting to match the signatures of each of the MMDEs associated with the SRC having one or more signatures removed therefrom. The process of cluster reduction for the purpose of generating SRCs may be performed in parallel and independently of the process described herein above. In such a case after either S**560** or S**570** the operation of S**580** takes place. In S**580** it is checked whether there are additional signatures to be processed and if so execution continues with S**510**; otherwise, execution terminates. SRCs may be stored in memory, such as DB **150**, for the purpose of being used by other elements comprising the DCC system **100**.

The CG **140** performs two tasks, it associates metadata to the SRCs provided by the CP **130** and it associates between similar clusters based on commonality of metadata. Exemplary and non-limiting methods for associating metadata with MMDEs is described in U.S. patent application Ser. No. 12/348,888, entitled "Methods for Identifying Relevant Metadata for Multimedia Data of a Large-Scale Matching System", filed on Jan. 5, 2009, assigned to common assignee (the "'888 Application"), and which is hereby incorporated for all that it contains. One embodiment of the '888 Application includes a method for identifying and associating metadata to input MMDEs. The method comprises comparing an input first MMDE to at least a second MMDE; collecting metadata of at least the second MMDE when a match is found between the first MMDE and at least the second MMDE; associating at least a subset of the collected metadata to the first MMDE; and storing the first MMDE and the associated metadata in a storage.

Another embodiment of the '888 Application includes a system for collecting metadata for a first MMDE. The system comprises a plurality of computational cores enabled to receive the first MMDE, each core having properties to be statistically independent of each other core, each generate responsive to the first MMDE a first signature element and a second signature element, the first signature element being a robust signature; a storage unit for storing at least a second MMDE, metadata associated with the second MMDE, and at least one of a first signature and a second signature associated with the second MMDE, the first signature being a robust signature; and a comparison unit for comparing signatures of MMDEs coupled to the plurality of computational cores and further coupled to the storage unit for the purpose of determining matches between multimedia data elements; wherein responsive to receiving the first MMDE the plurality of computational cores generate a respective first signature of said first MMDE and/or a second signature of said first MMDE, for the purpose of determining a match with at least a second MMDE stored in the storage and associating metadata associated with the at least second MMDE with the first MMDE.

Similar processes to match metadata with a MMDE or signatures thereof may be used. Accordingly, each SRC is associated with metadata which is the combination of the metadata associated with each of the signatures that are included in the respective SRC, preferably without repetition of metadata. A plurality of SRCs having metadata may now be associated to each other based on the metadata and/or partial match of signatures. For example, and without limitation, if the metadata of a first SRC and the metadata of a second SRC overlap more than a predetermined threshold level, for example 50% of the metadata match, they may be considered associated clusters that form a concept structure. Similarly, a second threshold level can be used to determine if there is an association between two SRCs where at least a number of signatures above the second threshold are identified as a match with another SRC. As a practical example one may want to consider the concept of Abraham Lincoln where images of the late President and features thereof, appear in a large variety of photographs, drawings, paintings, sculptures and more and are associated as a concept structure of the concept "Abraham Lincoln". Each concept structure may be then stored in memory, for example, the DB **150** for further use.

FIG. **6** shows an exemplary and non-limiting flowchart **600** of the operation of the CG **140**. In S**610** the CG **140** receives a SRC from either the CP **130** or by accessing memory, for example, the DB **150**. In S**620** metadata are generated for the signatures of the SRC, for example in accordance with the principles described hereinabove. A list of the metadata is created for the SRC preferably with no metadata duplication. In one embodiment the commonality of metadata is used to signify the strength of the metadata with respect to a signature and/or the SRC, i.e., a higher number of metadata repetitions is of more importance to the SRC than a lower number of repetitions. Furthermore, in one embodiment a threshold may be used to remove those metadata that have a significantly low rate of repetition as not being representative of the SRC.

In S**630** the SRC is matched to previously generated SRCs to attempt to find various matches, as described, for example, hereinabove in more detail. In S**640**, it is checked if at least one match was found and if so, execution continues with **S650**; otherwise, execution continues with **S660**. In **S660** the SRC is associated with one or more of the concept structures to which the SRC has been shown to match. In **S660** it is checked whether additional SRCs are to be received and if so execution continues with **S610**; otherwise, execution terminates.

A person skilled in the art would now appreciate the advantages of the DCC system **100** and methods thereof. The DCC system **100** is capable of creating automatically and in an unsupervised fashion concept structures of a wide variety of MMDEs. When checking a new MMDE it may be checked against the concept structures stored, for example, in the DB **150**, and upon detection of a match providing the concept information about the MMDE. With the number of concept structures being significantly lower than the number of MMDEs the solution is cost effective and scalable for the purpose of identification of content of a MMDE.

As noted above the creation of a concept structure seeds from a set of initial training set of MMDEs that are either input to system or saved in a central repository. In some cases a user of the DCC system **100** may request for a concept structure that has not existed in the system **100** and there is no initial training set to create the requested concept structure. According to the disclosed embodiments, such a concept structure is created through a representation of known concept structures (hereinafter "sub-concepts") existing in the DCC system **100** (hereinafter "sub-concepts"). The sub-concepts provide sparse representation of a (un-known) concept structure request to be created.

FIG. **7** shows an exemplary and non-limiting flowchart of a method for generating concept structures according to one embodiment. In **S710**, a request to generate a new concept structure is received. The request may be from a user of the DCC system **100**. The request is accomplished by a MMDE and optional one or more keywords describing the concept structure to be generated. The communication with the DCC system **100** is through, for example, a server or a client node being connected to the DDC system **100** a through a network, which may be the Internet, LAN, and the like.

In **S720**, the input MMDE is analyzed by the DCC system **100** in order to determine if a concept structure can be generated. This typically includes querying if the DCC system **100** includes or can access an initial training set for the creation of the request concept structure. In another embodiment, a check is made by the DCC system **100** if the MMDE fully matches one or more concept structures maintained by the DCC system **100**. A full match concept structure can be found by the CG **140**. To find a matching concept structure at least one signature is generated for the input MMDE. Then the generated signature(s) is matched to a SRC of each concept structure. If the signature(s) generated for the MMDE and a respective SRC overlap in more than a first predetermined threshold level (e.g., 85% overlap), the MMDE is considered to fully match the concept structure of the respective SRC.

In **S730**, it is checked whether at least one fully matching concept structure or an initial training set for the creation of a concept structure is found. That is, it is checked if the DCC system can generate the requested concept structure using the techniques discussed above. If so, execution continues with **S735**, where the received MMDE and optionally the keywords are fed to the DCC system **100** for generation of a concept structure as discussed above, for example with respect to FIG. **1**. Then execution ends.

Otherwise, execution continues with **S740** where it is checked if the DCC system **100** maintains at least one concept structure that partially matches the received MMDE. In an embodiment, **S740** includes querying again the DCC system **100** to find a partial matching concept by the CG **140**. To this end, at least one signature is generated for the input MMDE by the SG **120** (or the signatures created in **S720** are utilized for this purpose). Then the generated signature(s) is matched to a SRC of each concept structure maintained by the DCC system **100**. If the at least one signature generated for the MMDE and a respective SRC overlap in more than a second predetermined threshold level (e.g., 45% overlap), the MMDE is considered to partially match the concept structure of the respective SRC. It should be noted that a value of the second predetermined threshold level (used in **S740**) is less than a value of the first predetermined threshold level, in order to determine a partial match of the received MMDE to a concept structure. Each partial matching concept structure is defined hereinafter as a "sub-concept."

In **S750**, it is checked if at least one sub-concept was found, and if so execution proceeds to **S760**; otherwise, execution ends. In **S760**, another check is made to determine if the found sub-concepts satisfy a set of predefined logic rules. A predefined logic rule is a condition indicating a potential relation between a sub-concept to the concept structure (or the input MMDE) to be created. For example, if the input MMDE is of a 'nose' and a likely sub-concept is of a 'face', then the predefined logic rule is that the MMDE (e.g., nose) should be part of the sub-concept (e.g., face). In an embodiment, the predefined logic rules are input by a user of the DCC system **100**. Each sub-concept can be matched against the set of logic rules and/or any combination of two or more sub-concepts can be matched against the set of logic rules.

If **S760** results with an affirmative answer, execution proceeds to **S770**; otherwise, execution ends. In **S770**, a new concept structure is created using one or more sub-concepts that satisfy the set of predefined rules. That is, the new concept structure is represented by sub-concepts satisfying the rules. The metadata for the new concept structure may be keywords input by the user and/or metadata derived from the representative sub-concepts. In an embodiment, the new concept structure includes a linked-list of SRCs of sub-concepts satisfying the rules. The new concept structure may be saved in the DB **150** and returned to the user. In **S780** it is checked if there are additional requests to be processed, and if so execution returns to **S710**; otherwise, execution ends.

FIG. **8** is a schematic diagram illustrating the process for generating a concept structure as discussed in FIG. **7**. A number of 10 concept structures **810-1** through **810-10** are maintained by the DCC system **100**. An input MMDE **805** partially matches concept structures **810-1**, **810-3**, **810-5** and **810-7**. Thus, there are 4 sub-concepts **811-1**, **811-2**, **811-3**, and **811-4** respective of the concept structures **810-1**, **810-3**, **810-5**, and **810-7**. According to this example, only sub-concepts **811-2** and **811-3** satisfy a predefined logic rule. Therefore, a concept structure **820** generated for the MMDE **805** is represented by concept structures **810-3** and **810-5** (related to sub-concepts **811-2** and **811-3**).

As a non-limiting example, a user may request to create a concept structure of a motorcycle's headlight, providing a picture of such a headlight, assuming that the DB **150** does not contain a training set and/or concept structures that fully match the input picture. According to this example, a sub-concept of a car headlight and many sub-concepts, i.e., partially matching concept structures of different vehicles (e.g., of cars, tracks, and motorcycles of different makes and models) are found with respect to the input picture.

The sub-concept of the headlight may be determined based on a visual match or a sub-concept that its SRC mostly overlay the picture's signature. An exemplary predefined logic rule is that the sub-concepts of vehicles with two wheels should be considered. Therefore, a concept structure created for the input headlight picture is represented using the concept structures related to the sub-concept of the headlight and sub-concepts of two-wheel vehicles. The new concept structure may be saved in the DB **150**.

The embodiments disclosed herein can be implemented as hardware, firmware, software, or any combination thereof. Moreover, the software is preferably implemented as an application program tangibly embodied on a program storage unit or computer readable medium consisting of parts, or of certain devices and/or a combination of devices. The application program may be uploaded to, and executed by, a machine comprising any suitable architecture. Preferably, the machine is implemented on a computer platform having hardware such as one or more central processing units ("CPUs"), a memory, and input/output interfaces. The computer platform may also include an operating system and microinstruction code. The various processes and functions described herein may be either part of the microinstruction code or part of the application program, or any combination thereof, which may be executed by a CPU, whether or not such computer or processor is explicitly shown. In addition, various other peripheral units may be connected to the computer platform such as an additional data storage unit and a printing unit. Furthermore, a non-transitory computer readable medium is any computer readable medium except for a transitory propagating signal.

All examples and conditional language recited herein are intended for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future, i.e., any elements developed that perform the same function, regardless of structure.

What we claim is:

1. A method for generating concept structures, comprising:

receiving a request to create a new concept structure, wherein the request includes at least a multimedia data element (MMDE) related to the new concept structure;

generating, by a signature generator, at least one signature for the MMDE;

querying a deep-content-classification (DCC) system using the at least one generated signature to find at least one sub-concept, wherein the sub-concept is a concept structure that partially matches the received MMDE, wherein the MMDE is determined to partially match the concept structure when the at least one generated signature and a signature of the concept structure overlap in more than a predetermined threshold level;

checking if the at least one sub-concept satisfies at least one predefined logic rule; and

generating the new concept structure using one or more matching sub-concepts out of the at least one sub-concept that satisfies the at least one predefined logic rule.

2. The method of claim **1**, further comprising:

saving the generated new concept structure in a database communicatively connected to the DCC system.

3. The method of claim **1**, wherein the predefined logic rule indicates a potential relation between the one or more sub-concepts and the new concept structure.

4. The method of claim **1**, wherein the one or more sub-concepts satisfying the at least one predefined logic rule provide sparse representation of the new concept structure.

5. The method of claim **1**, wherein the new concept structure is generated using the one or more sub-concepts if the database does not contain a training set of MMDEs for creation of a new concept structure.

6. The method of claim **1**, wherein the MMDE is at least one of: an image, graphics, a video stream, a video clip, an audio stream, an audio clip, a video frame, a photograph, an image of signals, a medical signal, a geophysical signal, a subsonic signal, a supersonic signal, an electromagnetic signal, and an infrared signal.

7. The method of claim **1**, wherein the DCC system includes:

an attention processor (AP) for generating a plurality of items from the received sensory signal and determining which of the generated items are of interest for signature generation;

the signature generator (SG) for generating at least one signature responsive to at least one item of interest of the sensory signal; and

a concept generator (CG) for matching between the at least one signature generated responsive to at least one item of interest of the sensory signal and a plurality of signature reduced clusters associated with a plurality of cluster structures to identify at least the first set of metadata.

8. A non-transitory computer readable medium having stored thereon instructions for causing one or more processing units to execute the method according to claim **1**.

9. A system for generating concept structures, comprising:

an interface to a network for receiving a request to create a new concept structure, wherein the request includes at least a multimedia data element (MMDE) related to the new concept structure;

a signature generator;

a processor; and

a memory connected to the processor, the memory contains instructions that when executed by the processor, configure the system to:

generate, by the signature generator, at least one signature to the MMDE;

query a deep-content-classification (DCC) system using the at least one generated signature to find at least one sub-concept, wherein the sub-concept is a concept structure that partially matches the received MMDE, wherein the MMDE is determined to partially match the concept structure when the at least one generated signature and a signature of the concept structure overlap in more than a predetermined threshold level;

check if the at least one sub-concept satisfies at least one predefined logic rule; and

generate the new concept structure using one or more matching sub-concepts out of the at least one sub-concept that satisfies the at least one predefined logic rule.

10. The system of claim **9**, wherein the system is further configured to:

save the generated new concept structure in a database communicatively connected to the DCC system.

11. The system of claim **10**, wherein the predefined logic rule indicates a potential relation between the one or more sub-concepts and the new concept structure.

12. The system of claim **9**, wherein the one or more sub-concepts satisfying the at least one predefined logic rule provide sparse representation of the new concept structure.

13. The system of claim **9**, wherein the new concept structure is generated using the sub-concepts if the database does not contain a training set of MMDEs for creation of the concept structure.

14. The system of claim **9**, wherein the MMDE is at least one of: an image, graphics, a video stream, a video clip, an audio stream, an audio clip, a video frame, a photograph, an image of signals, a medical signal, a geophysical signal, a subsonic signal, a supersonic signal, an electromagnetic signal, and an infrared signal.

15. The system of claim **9**, wherein the DCC system includes:

an attention processor (AP) for generating a plurality of items from the received sensory signal and determining which of the generated items are of interest for signature generation;

the signature generator (SG) for generating at least one signature responsive to at least one item of interest of the sensory signal; and

a concept generator (CG) for matching between the at least one signature generated responsive to at least one item of interest of the sensory signal and a plurality of signature reduced clusters associated with a plurality of cluster structures to identify at least the first set of metadata.

16. The method of claim **1**, wherein the MMDE is determined to partially match the concept structure when the at least one generated signature and a signature of the concept structure overlap less than a second predetermined threshold level which when at least equaled indicates that the MMDE fully matches the concept structure.

17. The system of claim **9**, wherein the MMDE is determined to partially match the concept structure when the at least one generated signature and a signature of the concept structure overlap less than a second predetermined threshold level which when at least equaled indicates that the MMDE fully matches the concept structure.

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